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Dated 10 December 2003

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APPLICATION NO.: New U.S. Application
FILED: December 23, 2003
FOR: AN ELECTROSURGICAL GENERATOR
ATTORNEY DOCKET NO.: 117343

Patents Form 1/77

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30JUL03 E826249-1 001038
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2. Patent application number *(The Patent Office will fill in this part)*	0317728.4	29 JUL 2003
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Gyrus Medical Limited Fortran Road St Mellons Cardiff CF3 0LT United Kingdom	
Patents ADP number *(if you know it)*	580911003	
If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom	
4. Title of the invention	An Electrosurgical Generator	
5. Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	WITHERS & ROGERS Goldings House 2 Hays Lane London SE1 2HW	
Patents ADP number *(if you know it)*	1776001	
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AN ELECTROSURGICAL GENERATOR

This invention relates to an electrosurgical generator for supplying radio frequency (RF) power to an electrosurgical instrument, and primarily to a generator having a series-resonant output network.

Conventionally, electrosurgical generators make use of a configuration comprising voltage source coupled to an electrosurgical instrument via a coupling capacitor which defines a matched output impedance between 50 and 500 ohms. Such a configuration produces a power-versus-load impedance characteristic having a power maximum at a matched impedance, with power falling off progressively on each side of this peak. In practice, when conducting electrosurgery, the load impedance can change over a very wide range, resulting in unpredictable clinical effects.

To deal with this problem, it is known to provide an RF output stage capable of providing an impedance match over a wide range. This has the disadvantage that rapid load impedance changes can produce large output voltage excursions. An alternative approach is to control the DC supply to the RF output stage in response to feedback signals in order that the delivered power is virtually continuous. This may be done by adjusting the power supply DC voltage or by maintaining the supplied DC power constant. These techniques lead to a power versus load impedance characteristic which is virtually flat over a range of impedances, but one limitation is that it is difficult to control the delivery of energy when initiating tissue cutting or vaporisation (as opposed to tissue coagulation). To cut or vaporise tissue using radio frequency power, the initial low impedance load presented by the tissue or surrounding fluid needs to be brought to a higher impedance in order to strike an arc. Delivering too much energy can result in burns adjacent the operative site, excessive smoke, or instrument failure. Delivering too little energy causes a significant delay and can result in unwanted tissue coagulation.

According to a first aspect of the present invention, an electrosurgical generator for supplying RF power to an electrosurgical instrument comprises an RF output stage

having a least one RF power device, at least one pair of output lines for delivering RF power to the instrument, and a series-resonant output network coupled between the RF power device and the said pair of output lines, wherein the output impedance of the output stage at the output lines is less than $200/\sqrt{P}$ ohms, where P is the maximum continuous RF output power of the generator in watts. When the generator is configured for wet field surgery, e.g. for use with the electrode or electrodes of the instrument immersed in a conductive fluid such as saline, the maximum continuous power is preferably in the region of 300W to 400W. Accordingly, if the maximum output power is 400W, the output impedance is less than 10 ohms. Dry field electrosurgery, i.e. with the electrode or electrodes not normally immersed, requires less RF output power. In this case, the generator may be configured such that the maximum continuous RF output power is in the region of 16W, in which case that the output impedance is then less than 50 ohms. In both such cases, the figures are obtained when operating with an output voltage for cutting or vapourising tissue, i.e. at least 300V peak. The output impedance is preferably less than $100/\sqrt{P}$ ohms, which yields maximum output impedance values of 5 ohms and 25 ohms at the above power outputs.

It will be understood that when the RF output of the generator is pulsed, i.e. when RF energy is supplied to a load in bursts, generally as an RF sine wave, the maximum continuous power is the average power measured over several such bursts.

According to another aspect of the invention, an electrosurgical generator for supplying RF power to an electrosurgical instrument for cutting or vaporising tissue comprises an RF output stage having: at least one RF power device, at least one pair of output lines for delivering RF power to the instrument, and a series-resonant output network coupled between the RF power device and the said pair of output lines, the network being configured such that the maximum rate of rise of the output current at the output lines is less than $(\sqrt{P})/4$ amps per microsecond, P being as defined above.

Accordingly, for a typical maximum continuous RF output power of 400W for wet field electrosurgery, the maximum rate of rise of the output current amplitude, generally when the output lines are short-circuited at the maximum power setting of

the generator, is less than 5A/μs. With *P* at a typical value of 16W for dry field electrosurgery, the rate of rise of the output current amplitude is less than 1A/μs.

In a preferred generator in accordance with the invention, there is protection circuitry responsive to a predetermined electrical condition indicative of an output current overload, e.g. due to short-circuitry of the output lines, substantially to interrupt the RF power supplied to the series-resonant output network. The protection circuitry is responsive to short-circuiting with sufficient speed that the supply of RF power to the output network is cut off within a time period corresponding to no more than 20 cycles of the delivered RF power. The protection circuitry is preferably much faster, e.g. being operable to interrupt power delivery within 3 cycles or even 1 cycle. The effect of the series-resonant output network is to delay the build up of current in a fault condition such as when a very low impedance or a short circuit appears across the output lines. The applicants have found that an impedance transition from open to short circuit results in an effective short circuit across the RF power device only after several RF cycles. By arranging for the protection circuitry to respond quickly, the output stage can be disabled before that happens.

The use of an RF output stage with a relatively low output impedance means that the RF voltage output is substantially directly related to the DC supply voltage applied to the output stage (specifically to the RF power device or devices which it contains). In the preferred embodiment of the invention, each RF power device is operated in a switching mode with the result that a square wave output is applied to the series-resonant output network. The RMS voltage available at the output lines is directly proportional to the supply voltage. It follows that the maximum peak-to-peak output voltage is determined by the DC supply voltage and dynamic feedback to control output voltage is, as a result, not required in this embodiment.

The protection circuitry is preferably capable of disabling the output stage within one-and-a-half RF periods after onset of the above-mentioned predetermined electrical condition. Preferably, the predetermined electrical condition is indicative of an instantaneous current in the output stage exceeding a predetermined level, and the speed of response of the protection circuitry is such that the breaching of the

predetermined level by the instantaneous current is detected during the same RF cycle that it occurs. Such detection may be performed by connecting a current transformer in series between the RF power device or devices and the series-resonant output network, the secondary winding of the transformer being coupled to a comparator which receives on one of its inputs a voltage representation of the instantaneous current, i.e. substantially without filtering, in order to cause a change of state of the comparator output within the same RF half-cycle that the threshold is first exceeded, or within the subsequent half-cycle, depending on whether or not full wave rectification is applied ahead of the comparator. The predetermined instantaneous output level is preferably at least 5A for wet field electrosurgery, and typically 15A. The output current of the comparator is coupled to disabling circuitry for disabling the power device or devices when the comparator output changes state. The current shut-down aspect of the protection circuitry is not limited by impedance.

Generally, it is necessary only to interrupt power delivery for a short time. Consequently the protection circuitry includes a monostable stage operable in response to detection of the predetermined condition to disable the power device for a limited period determined by its time constant which is typically less than 20 cycles of the RF output.

Preferably, the generator has an RF source coupled to the power device or devices, the source including an oscillator defining the operating frequency of the generator. The series resonant output network is tuned to this operating frequency. Generally, the operating frequency is substantially constant during any given treatment cycle.

The preferred generator is arranged such that, for a given user setting, the RMS RF output voltage during each burst of RF energy is maintained to within 20 percent of a maximum value within a load impedance range of from $600/\sqrt{P}$ ohms to 1000 ohms, where P is as defined above. This can be achieved partly as a result of the series-resonant configuration of the output network.

To maintain the constant peak output voltage at low impedances, the power supply to the output stage includes a charge-storing element, preferably a capacitance in excess

of 1mF, the output devices being pulsed by a pulsing circuit so that they supply RF energy in bursts with the timing of the bursts, particularly the termination of each burst, being controlled in response to the output of a voltage sensing circuit coupled to the capacitance. The DC power supply voltage to the output stage is preferably 100V or greater. To avoid substantial decay of the supply voltage, the voltage sensing and pulsing circuits are arranged to terminate the individual pulses of RF energy when the sensed voltage falls below a predetermined level, typically set such that pulse termination occurs when the voltage falls by a predetermined percentage value of between 5 percent and 20 percent which, typically, corresponds to the peak RF voltage delivered at the output lines falling to a value between 25V and 100V below its starting value for the respective pulse. The RF energy delivered during each pulse is typically 60 joules for wet field electrosurgery and 2 joules for dry field electrosurgery. Peak power typically reaches at least 1kW, and preferably 4kW.

The very high peak power capability of the preferred wet field generator (in excess of 1kW) allows the impedance transition occurring at the start of a tissue cutting or vaporisation cycle to be completed very quickly since only voltages in excess of those required for arcing are delivered. This significantly reduces the delay and the unwanted coagulation effects of some prior art generators. The substantially constant voltage delivery leads to cutting or vaporisation occurring at consistent rates, regardless of changes in tissue type or engagement.

According to a further aspect of the invention a generator for supplying RF power to an electrosurgical instrument for cutting or vaporising tissue comprises an RF output stage having: at least one RF power device, at least one pair of output lines for delivering RF power to the instrument, and a series-resonant output network coupled between the RF power device and the said pair of output lines, wherein the generator is configured to be capable of maintaining a peak output voltage of at least 300V over a load impedance range of from $600/\sqrt{P}$ ohms to 1000 ohms, where P is the rated output power in watts. The rated output power is as defined in the International Electrotechnical Commission standard, IEC 60601-2-2.

According to yet a further aspect of the invention, there is provided an electrosurgical generator for supplying RF power to an electrosurgical instrument for cutting or vaporising tissue, wherein the generator comprises an RF output stage having: at least one RF power device, at least one pair of output lines for delivering RF power to the instrument, and a series-resonant output network coupled between the RF power device and the said pair of output lines, wherein the generator further comprises a power supply stage coupled to the RF output stage, the power supply stage having an energy storage capacitor capable of storing between 3 percent and 30 percent of the maximum continuous power P (in watts) of the generator in joules.

In another aspect of the invention, the energy delivery per pulse (in joules) is between 1 percent and 10 percent of the maximum continuous RF output power (in watts).

The invention also includes an electrosurgical generator for supplying RF power to an electrosurgical instrument for cutting or vaporising tissue, wherein the generator comprises an RF output stage having: at least one RF power device, at least one pair of output lines for delivering RF power to the instrument, and a series-resonant output network coupled between the RF power device and the output lines, and wherein the generator further comprises a pulsing circuit coupled to the output stage for pulsing the delivered RF power in such a way that the crest factor of the voltage developed across the output lines increases as the load impedance presented to the output lines decreases whilst the peak output voltage during pulses is maintained at a value greater than 300V. For wet field electrosurgery, the output impedance of the output stage is preferably less than 10 ohms and the crest factor varies by a ratio of at least 2:1 over a load impedance range of from $600/\sqrt{P}$ to 1000 ohms. For dry field electrosurgery, the output impedance figure is less than 50 ohms, and the crest factor varies by a ratio of at least 2:1 over a load impedance range of $600/\sqrt{P}$ to 50 kilohms.

By "crest factor" we mean the ratio of the peak voltage to the RMS voltage. In the case of a pulsed output waveform, the measurement is conducted over plurality of pulses.

The invention will now be described by way of example with reference to the drawings in which:-

Figure 1 is a general diagram showing an electrosurgery system including a generator in accordance with the invention and a bipolar electrosurgical instrument;

Figure 2 is a block diagram illustrating the main components of the generator;

Figure 3 is a simplified circuit diagram of an RF output stage forming part of the generator;

Figure 4 is an illustrative load curve for the generator of Figure 1; and

Figure 5 is a more detailed circuit diagram of the RF output stage.

Referring to Figure 1, a generator 10 has an output socket 10S providing a radio frequency (RF) output for an electrosurgical instrument in the form of an endoscope attachment 12 via a connection cord 14. Activation of the generator may be performed from the instrument 12 via a control connection in cord 14 or by means of a footswitch unit 16, as shown, connected separately to the rear of the generator 10 by a footswitch connection cord 18. In the illustrated embodiment, the footswitch unit 16 has two footswitches 16A and 18B for selecting a coagulation mode and a cutting mode of the generator respectively. The generator front panel has push buttons 20 and 22 for respectively setting coagulation and cutting power levels, which are indicated in a display 24. Push buttons 26 are provided as alternative means for selection between coagulation and cutting modes. The instrument 12 has a detachable loop electrode assembly 28 with a dual electrode structure and is intended for use in a saline field. It should be noted that the present generator is not limited to use with such an electrode assembly, nor to use in wet field surgery.

The generator will now be described in more detail with reference to Figure 2. It has an RF source in the form of an oscillator 40 which is connectible to an RF output stage 42. The output stage 42 comprises a mosfet power bridge forming part of a power mosfet and driver circuit 44, a current sensing element 46 and a resonant output

network 48. The oscillator 40 is configured to operate at a substantially constant RF frequency and the output network 48 is tuned to that frequency.

Power to the RF output stage 42, or, more specifically, to the power mosfets, is supplied from a DC power supply 50 via a supply rail 58. A 4.7mF reservoir capacitor 60 is connected between the supply rail 58 and ground. The voltage on the supply rail 58 is sensed by a voltage sensing circuit 62 which controls a first transmission gate 64 connected in series between the RF oscillator 40 and driver devices in the power mosfet and driver circuit 44.

The current sensing element 46 in the output stage 42 is a series-connected current transformer, the secondary winding of which is coupled to a first input of a comparator 66 which also receives on the other of its inputs a reference signal from a reference input 68. The output of the comparator controls a monostable 70 which, in turn, controls a second transmission gate 72 coupled in series with the gate 64 in the path between the oscillator 40 and the drivers in the power mosfet and driver circuit 44. The output network 48 supplies RF power to an output termination 74 which, in practice, is a pair of output lines, as will be described hereinafter. Operation of the generator is normally pulsed insofar as RF energy is supplied to the output lines 74 in bursts controlled by the combination of the voltage sensing circuit 62 and gate 64 which operates as part of a pulsing circuit. When the generator is activated, the voltage on the supply rail 58 tends to fall, at least when the load impedance coupled across output lines 74 is relatively low, owing to the discharge of reservoir capacitor 60. When the DC supply voltage on the supply rail 58 falls to a preset value, the output of the voltage sensing circuit 62 changes state and transmission gate 64 is driven to its open circuit condition, thereby disabling the power mosfet and driver circuit 44. The reservoir capacitor 60 then recharges and the voltage sensing circuit 62 causes the gate 64 to reconnect the oscillator 40 when the supply rail voltage reaches a second, higher present value. In this way it is possible to control the amount of energy delivered in each pulse.

The current sensing element 46, the comparator 66, the monostable 70 and the second transmission gate 72 act together as a protection circuit to protect the mosfet power devices in circuit 44 against excessive current drain caused, for instance, by a short

circuit across the output lines 74. The storage of energy in output network 48 delays the transfer of the short circuit across the output lines 74 to the power devices in the mosfet and driver circuit 44.

The electrical circuit condition sensed by the current sensing element 46 and the comparator 66 is the current flowing between the power mosfets in circuit 44 and the output network 48 rising to a level which could be indicative of a short circuit having been applied across the output lines 74. When the current reaches a preset current level, as detected by the comparator 66, the comparator output changes state and the monostable 70 causes the second transmission gate 72 to become open circuit, disabling the power mosfets and driver stage 44. The monostable time constant is typically set to 0.5 seconds or less, which allows a warning signal to be generated for alerting the user. However, owing to energy storage in the series-resonant circuit, it is possible to protect the RF power devices with a monostable time constant of about 20 RF cycles at an operating frequency of 400kHz.

The configuration of the output stage 42 is shown in principle in the simplified circuit diagram of Figure 3. Referring to Figure 3, the power mosfet and driver stage 44 shown in Figure 2 has a power mosfet bridge comprising a first push-pull pair of mosfet power devices Q1, Q2 and a second power mosfet device push-pull pair Q3, Q4, each pair having a respective output node which, when the pairs are driven 180° out of phase, produces a square wave at the frequency of the oscillator 40 (Figure 2) at the input to the series resonant output network 48. Each pair of power mosfets Q1, Q2; Q3, Q4 is coupled between the supply rail 58 and ground. Accordingly, since each of the mosfets is a virtual short circuit when driven "on", the voltage applied to the output network 48 swings virtually between ground and the supply rail voltages. The reservoir capacitor 60 shown in Figure 2 is, of course, connected across the respective power mosfet pairs, as shown in Figure 3.

The output network is series-resonant in that an inductor L1 and a resonating capacitor C2 are coupled in series between the output nodes 76, 78 of the first and second power mosfet pairs respectively. In this embodiment, the load resistance R_L constituted in practice by an electrosurgical instrument coupled between the output lines 74, and the tissue and/or fluid present across its electrode assembly, is connected

in series between inductor L1 and capacitor C2. As explained above, the series-resonant tuned circuit formed by inductor L1 and capacitor C2 acts as an energy storing device which delays the current build-up between the nodes of the power mosfet bridge Q1-Q4 should the load resistance R_L drop to a very low value. Another feature of this resonant arrangement is that it is a low impedance at one frequency only, which means that the delivered output signal consists almost exclusively of the fundamental component of the waveform produced by the power mosfets, conditional, of course, upon the frequency of resonance of the network 48 being the same as that of the operating frequency of the oscillator stage 40 (Figure 1).

One of the characteristics given to the generator by the output configuration described above with reference to Figure 3 is that, during each burst or pulse of RF energy it has an approximately constant voltage load curve, as shown by the power-versus-load impedance load curve shown in Figure 4. This characteristic is particularly suitable for cutting or vaporisation of tissue since it provides the high power required at low impedance without voltage overshoot. The low output impedance and high current required are provided by the direct coupling of the power mosfets to the supply rail and ground, and by the reservoir capacitor 60, even if a step-up transformer is coupled between the series-resonant elements L1, C2 and the output lines 74. It is possible, using this configuration, to keep the output impedance of the generator at the output lines 74 to 2 ohms or less. The implications which this has for peak current delivery in a fault condition leads to the need for a protection circuit such as that referred to above.

The RF output stage 42 is shown in more detail in Figure 5. As shown in Figure 5, the current sensing element 46 is a current transformer, coupled in series between one of the output nodes 76, 78 of the power mosfet bridge and one of the components L1, C2 of the series resonant output network, in this case between node 76 and the inductor L1. In this preferred generator, the normal DC supply voltage on supply rail 58 is about 120V. To strike an arc for the purpose of performing tissue cutting or vaporisation, a peak voltage in excess of 380V may be required. Accordingly, and for isolation purposes, the RF output network 48 includes a step-up isolating transformer TR1 to lift the peak output voltage to the region of 500V peak. The primary winding of the transformer TR1 has a tuning capacitor C3 coupled across it to yield a parallel-

resonant circuit tuned to the operating frequency to act as a shunt-connected trap. This improves the rejection of harmonics in the power signal supplied to the output lines 74., particularly when the output impedance is high, with the consequent benefit of reduced RFI (RF interference).

DC blocking is provided by a coupling capacitor C4 between the transformer TR1 secondary winding and one of the output lines 74.

The actual resonant frequency of the output network 48 is the result of several elements, these being (1) the main tuning elements represented by the lumped inductance L1 and the tuning capacitor C2, (2) the transformer leakage inductance and cross-coupling capacitance, (3) the DC blocking capacitance, C4, and (4) the inductive and capacitive loading of the connecting cable (not shown) between the output lines 74 and the electrosurgical instrument itself. The delay in the current build-up in a fault condition is due to the energy levels in this tuned arrangement. At resonance, this arrangement has a finite loss that may be represented by a series resistance, albeit a very small one. Dynamically, however, the energy levels in the resonant output network cannot be changed instantly. An impedance transition from an open to short circuit only presents a short circuit to the switching stage after several RF cycles at the operating frequency. The comparator 66 shown in Figure 2 is capable of detecting such an impedance transition within 1 to 1.5 cycles of the transition beginning at the output lines 74. This rapid response, as well as allowing the power mosfet and driver circuit 44 to be shut down before damage occurs, has the effect that the amount of energy delivered during a short circuit fault is very small.

Referring again to Figure 2 and, in particular, the voltage sensing and output stage pulsing circuits 62, 64, the very high peak powers which are achievable with the output stage described above with reference to Figures 4 and 5 have the benefit that, during power delivery into a low impedance, the voltage across the reservoir capacitor 60 decreases progressively after the instant of generator activation. The capacitor value is chosen to be sufficiently large to ensure that the low to high load impedance transition occurring at the start of a tissue cutting or vaporisation cycle can be produced in a single burst of RF energy. Typically, the amount of energy delivered during the initial burst is about 1 joule in a dry environment and between 10 to 20

joules in a wet field environment. The actual energy in the RF pulses or bursts is controlled by the threshold or thresholds set in the voltage sensing circuit 62, specifically by the difference in supply voltage between pulse initiation and pulse termination. Since the output stage has a very low output impedance, this difference voltage is apparent as a change in delivered RF voltage at the output. The capacitor 60 is, therefore, made sufficiently large (in this embodiment 4.7mF) that the change in voltage represents only a minor proportion of the absolute voltage at the output. Thus, if the delivered output voltage is a sine wave with a peak voltage of 500V, the supply voltage on supply rail 58, the size of the capacitor 60 and the transformer TR1 step-up ratio are chosen such that the output voltage drops by no more than 100V peak (20 percent) during an RF burst. In this preferred embodiment, the output voltage drop is about 50V peak or 10 percent.

One of the effects of preventing the supply of lower voltages to the output is that, in a tissue cutting or vaporisation tissue cycle, the voltage is not allowed to drop to a level at which undesirable coagulation effects occur.

The preferred generator in accordance with the present invention allows the DC energy fed to the reservoir capacitor 60 to be altered so that the time period during which a cutting voltage is present at the output can be altered. In practice, owing to the low output impedance of the generator, this time period is directly proportional to the stored energy.

The control methodology, whereby RF energy bursts or pulses are controlled according to voltage thresholds sensed across a reservoir capacitor, allows very low duty cycles to be used, permitting tissue cutting or vaporisation at low average powers. Indeed, it is possible to operate with less than 5 watts average power (averaged over several capacitor charging and discharging cycles). Accordingly, the generator has uses in low power as well as high power applications.

CLAIMS

1. An electrosurgical generator for supplying radio frequency (RF) power to an electrosurgical instrument for cutting or vaporising tissue, wherein the generator comprises an RF output stage having:

at least one RF power device,

at least one pair of output lines for delivering RF power to the instrument, and

a series-resonant output network coupled between the RF power device and the said pair of output lines,

and wherein the output impedance of the output stage at the output lines is less than $200/\sqrt{P}$ ohms, where P is the maximum continuous RF output power of the generator in watts.

2. A generator according to claim 1, wherein the output impedance is less than $100/\sqrt{P}$ ohms.

3. A generator according to claim 1 or claim 2, further comprising protection circuitry responsive to application of a short circuit across the output lines, and wherein the series-resonant output network is such that the rate of rise of the output current at the output lines when the short circuit is applied is less than $(\sqrt{P})/4$ amps per microsecond.

4. A generator according to claim 1 or claim 2, further comprising protection circuitry responsive to a predetermined electrical condition indicative of an output current overload substantially to interrupt the RF power supplied to the output network.

5. A generator according to claim 3 or claim 4, wherein the protection circuitry is responsive to the application of a short circuit at the output lines with sufficient speed that the supply of RF power to the output network is interrupted within a time period corresponding to no more than 20 RF cycles of the delivered RF power.

6. A generator according to claim 5, wherein the time period corresponds to less than 3 cycles of the delivered RF power.

7. A generator according to claim 6, wherein the time period corresponds to less than 1 cycle of the delivered RF power.

8. A generator according to any preceding claim, having an RF source coupled to the power device, the source defining the operating frequency of the generator, wherein the series-resonant output network is tuned to the operating frequency.

9. A generator according to claim 8, wherein the source is arranged such that the operating frequency is substantially constant.

10. A generator according to any of claims 3 to 7, wherein the predetermined electrical condition is indicative of an instantaneous current in the output stage exceeding a predetermined level, and wherein the speed of response of the protection circuitry is such that the said condition is detected within the RF cycle during which the instantaneous current exceeds the said level.

11. A generator according to any preceding claim, including protection circuitry which has a current sensing arrangement coupled in series between the power device and the series-resonant output network and, coupled to the pick-up arrangement, a comparator having a first input coupled to the pick-up arrangement and a second input coupled to a reference level source, and disabling circuitry coupled to an output of the comparator to disable the power device when the comparator output changes state in response to the instantaneous current sensed by the pick-up arrangement exceeding the predetermined level as set by the reference level source.

12. A generator according to any of claims 3 to 7, 10 and 11, wherein the protection circuitry includes a monostable stage and is operable, in response to detection of the said predetermined condition, to disable the power-device for a limited period determined by a time constant of the monostable stage, the time constant corresponding to less than 20 cycles of the operating frequency of the generator.

13. A generator according to any preceding claim, arranged such that the RMS RF output voltage is substantially constant within a load impedance range of from $600/\sqrt{P}$ ohms to 1000 ohms where P is as defined hereinabove.

14. A generator according to any preceding claim, including:

a power supply stage coupled to the RF output stage, the power supply including a charge-storing element for supplying power to the power device or devices and a voltage-sensing circuit arranged to sense the voltage supplied to the RF output stage by the charge-storing element; and

a pulsing circuit coupled to the voltage sensing circuit for pulsing the or each power device, the arrangement of the voltage sensing and pulsing circuits being such that the timing of the pulses is controlled in response to the sensed voltage.

15. A generator according to claim 14, wherein the voltage sensing circuit and the pulsing circuit are arranged to terminate individual pulses of RF energy delivered by the RF power device or devices when the sensed voltage falls below a predetermined level.

16. A generator according to claim 15, wherein the predetermined level is set such that the pulse termination occurs when the voltage falls by a predetermined percentage value of between 5 percent and 20 percent.

17. A generator according to claim 15 or claim 16, wherein the predetermined level is set such that pulse termination occurs when the peak RF voltage delivered at the output lines has fallen to a value of between 25V and 100V below its starting value for the respective pulse.

18. An electrosurgical generator for supplying radio frequency (RF) power to an electrosurgical instrument, wherein the generator comprises an RF output stage having at least one RF power device, at least one pair of output lines for delivering RF power to the instrument, and a series-resonant output network coupled between

the RF power device and the output lines, the generator further comprising protection circuitry responsive to a short circuit across the output lines, wherein the output impedance of the output stage is less than $200/\sqrt{P}$ ohms, where P is the maximum continuous RF output power of the generator in watts, and wherein the protection circuitry is responsive to the said short circuit sufficiently quickly to disable the power device before the current passing therethrough rises to a rated maximum current as a result of the short circuit.

19. A generator according to claim 18, wherein the or each said power device is disabled in response to application of the short circuit to the output lines, the disabling occurring in a time period corresponding to less than 3 RF cycles.

20. An electrosurgical generator for supplying radio frequency (RF) power to an electrosurgical instrument for cutting or vaporising tissue, wherein the generator comprises an RF output stage having:

at least one RF power device,

at least one pair of output lines for delivering RF power to the instrument, and

a series-resonant output network coupled between the RF power device and the said pair of output lines,

and wherein the generator is configured to be capable of maintaining a peak output voltage of at least 300V over a load impedance range of from $600/\sqrt{P}$ ohms to 1000 ohms, where P is the maximum continuous RF output power in watts.

21. An electrosurgical generator for supplying radio frequency (RF) power to an electrosurgical instrument for cutting or vaporising tissue in wet field electrosurgery, wherein the generator comprises an RF output stage having:

at least one RF power device,

at least one pair of output lines for delivering RF power to the instrument, and

a series-resonant output network coupled between the RF power device and the said pair of output lines,

and wherein the output impedance of the output stage at the output lines is less than 10 ohms.

22. An electrosurgical generator for supplying radio frequency (RF) power to an electrosurgical instrument for cutting or vaporising tissue in dry field electrosurgery, wherein the generator comprises an RF output stage having:

at least one RF power device,

at least one pair of output lines for delivering RF power to the instrument, and

a series-resonant output network coupled between the RF power device and the said pair of output lines,

and wherein the output impedance of the output stage at the output lines is less than 50 ohms.

23. An electrosurgical generator for supplying radio frequency (RF) power to an electrosurgical instrument for cutting or vaporising tissue, wherein the generator comprises an RF output stage having:

at least one RF power device,

at least one pair of output lines for delivering RF power to the instrument, and

a series-resonant output network coupled between the RF power device and the output lines,

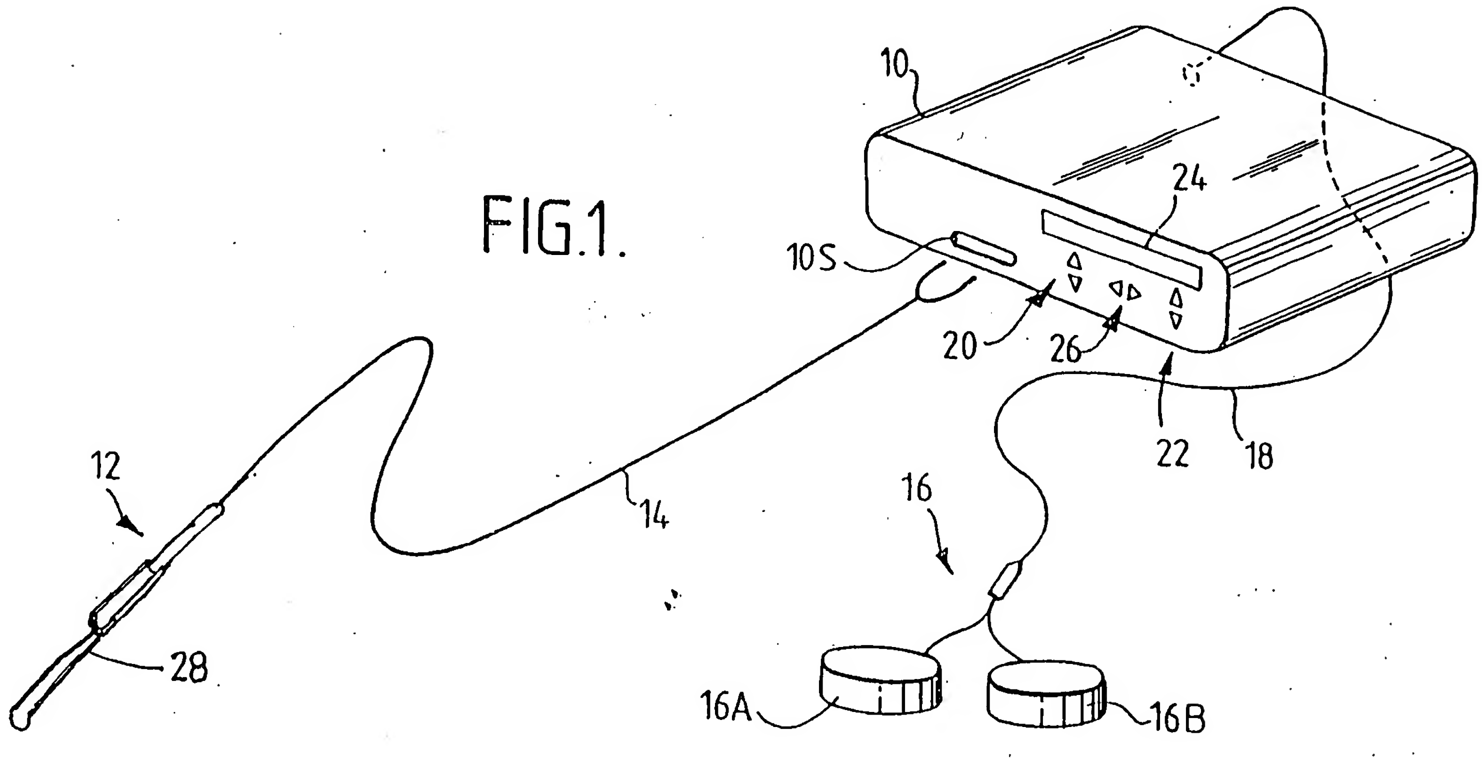
and wherein the generator further comprises a pulsing circuit coupled to the output stage for pulsing the delivered RF power in such a way that the crest factor of the voltage developed across the output lines increases as the load impedance presented to the output lines decreases whilst the peak voltage during pulses is maintained at a value greater than 300V.

24. A generator according to claim 23, wherein the output impedance of the output stage is less than 10 ohms and the crest factor varies by a ratio of at least 2:1 over a load impedance range of from 10 ohms to 1000 ohms.

25. A generator according to claim 23, wherein the output impedance at the output lines is less than 50 ohms and the crest factor varies by a ratio of at least 2:1 over a load impedance range of from 50 ohms to 50 kilohms.

26. An electrosurgical generator constructed and arranged substantially as herein described and shown in the drawings.

FIG.1.



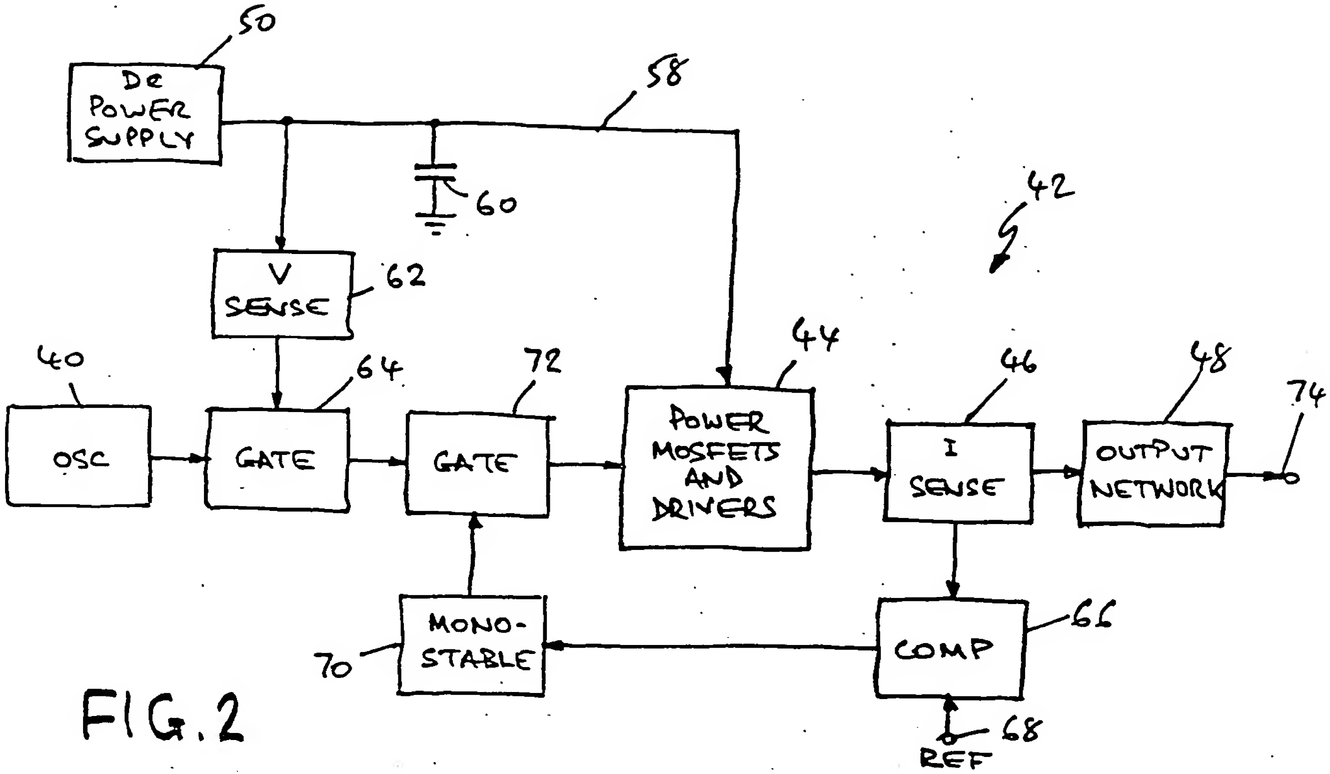

50
DC POWER SUPPLY
58
60
42
V SENSE
62
40
64
72
44
46
48
74
OSC
GATE
GATE
POWER MOSFETS AND DRIVERS
I SENSE
OUTPUT NETWORK
MONO-STABLE
COMP
66
70
68
REF

FIG. 2

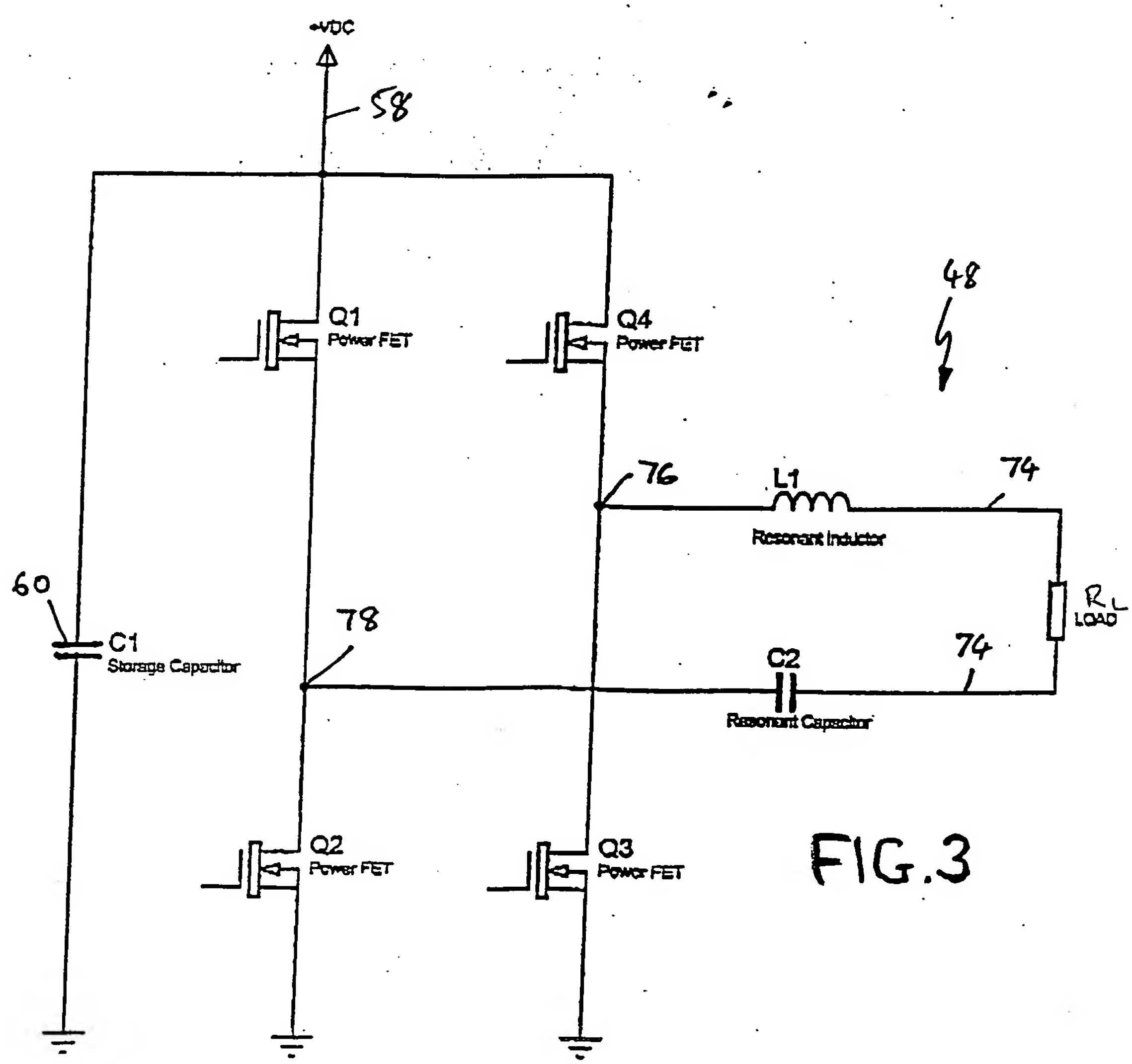
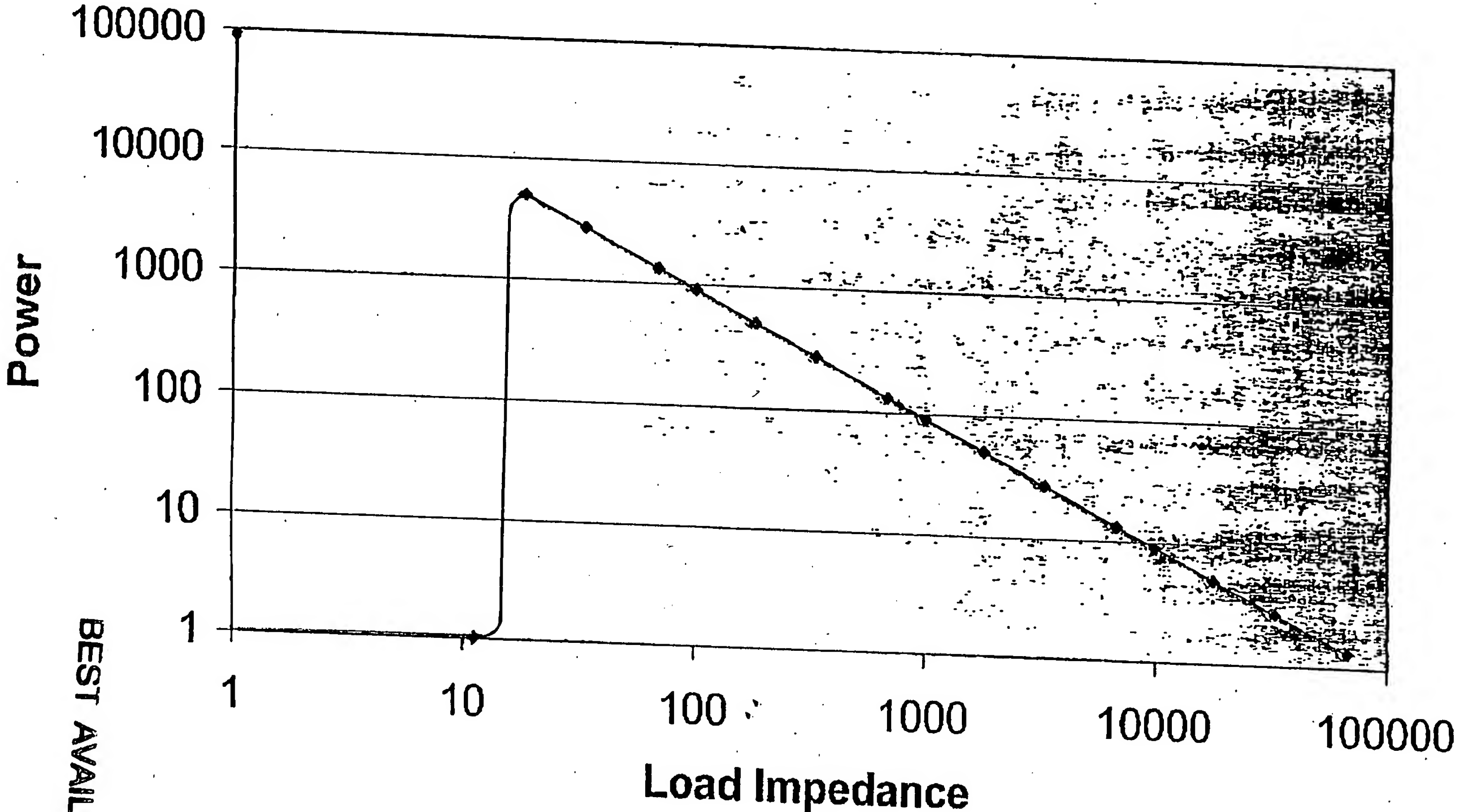

+VDC
58
48
Q1
Power FET
Q4
Power FET
76
L1
74
Resonant Inductor
60
C1
Storage Capacitor
78
R L
LOAD
C2
74
Resonant Capacitor
Q2
Power FET
Q3
Power FET

FIG. 3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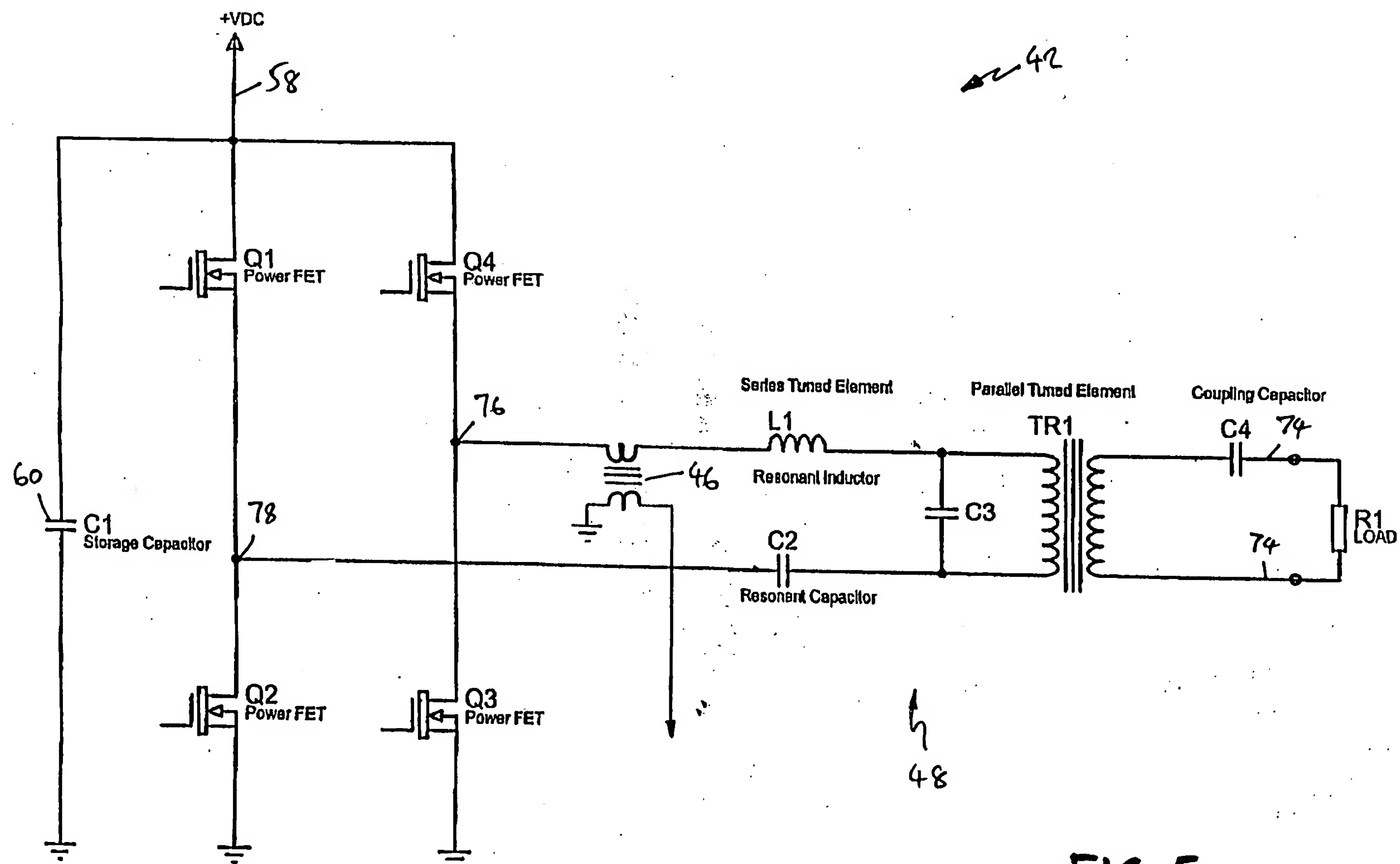
10000
1000
100
10
1
Power
1
10
100
1000
10000
100000
Load Impedance

FIG. 4

4/4



+VDC
58
42
Q1
Power FET
Q4
Power FET
Q2
Power FET
Q3
Power FET
60
C1
Storage Capacitor
78
76
46
Series Tuned Element
L1
Resonant Inductor
C2
Resonant Capacitor
Parallel Tuned Element
TR1
C3
Coupling Capacitor
C4
74
74
R1
LOAD
48

FIG.5